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Environment

Submitted to:
USEPA Region 8
Denver, CO

Submitted by:
Atlantic Richfield Company
La Palma, CA
April 2016

Work Plan

St. Louis Tunnel Hydraulic Controls Interim Risk Reduction Measures

Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01 Rico, Colorado

AECOM

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Rico, Colorado

Prepared for: Atlantic Richfield Company

Prepared by: AECOM Technical Services, Inc.

April 18, 2016

Contents

List of Figures

Introduction

This document constitutes the Work Plan for proposed interim risk reduction measures to be implemented at the St. Louis Tunnel during the spring and summer of 2016. The measures proposed herein are part of the ongoing response to the requirements of the U.S. Environmental Protection Agency (USEPA) Unilateral Administration Order (UAO) (USEPA, 2011a[1]) and Removal Action Work Plan (RAWP) (USEPA, 2011b[2]), specifically Subtask D2 of Task D, "Final Design of Adit Hydraulic Controls." The Work Plan addresses all of the relevant topics outlined in an email from Steve Way/EPA to Tony Brown/AR(BP) dated April 1, 2016, Subject: Project Planning – Documentation 2016.

I. Site Description

The St. Louis Tunnel (SLT) acts as a low-level drain for mine water and natural groundwater discharges from the extensive interconnected underground mine workings within the faulted and fractured bedrock of Telescope Mountain and Dolores Mountain. The pH neutral mine water discharge is characterized by elevated concentrations of dissolved metals including zinc, cadmium, and copper. Lead, manganese and iron, and will require treatment as part of the remedy under the UAO prior to discharge to the river. The surface water discharges from the SLT flow through a series of constructed settling and treatment ponds known as the St. Louis Ponds System, and eventually discharge to the Dolores River.

The SLT was originally driven in the 1930s from its historic portal location through approximately 330 feet of colluvium/talus at the base of Telescope Mountain, and then into bedrock of the Hermosa Formation. During the 1950s, much but not all of the colluvium / talus overlying this reach of the tunnel was removed in a large horseshoe-shaped, steeply-sloped excavation into the base of the mountain, resulting in what is now referred to as the terrain trap. The first approximately 250 feet of the tunnel immediately beyond the historic portal location has collapsed, apparently due to borrowing from the remaining overlying colluvium / talus deposits in the 1990s. The current condition in this reach is a tangle of broken timbers and lagging among a heterogeneous mix of sand to large boulder size blocks resulting in unstable voids of varying size and shape. The discharge from the tunnel is impeded at the east (upgradient) end of the open, collapsed reach behind what is referred to as a debris plug. This reach is inaccessible, but is known to be backing up mine water in the SLT up to 6 feet above the tunnel crown (roof) level based on water levels monitored at monitoring well AT-2. A second debris plug further into the tunnel is inferred based on monitoring of water levels at monitoring well BAH-01, with heads up to 11 feet above the tunnel roof. Some amount of metals-precipitate sludge has settled over time on the floor of the tunnel in the backed-up pools of mine water.

[1] USEPA, 2011a. *Unilateral Administrative Order for Removal Action (UAO)*, U.S. EPA Region 8, CERCLA Docket No. CERCLA-08 20011-0005, dated March 23.

[2] USEPA, 2011b. *Removal Action Work Plan, Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01, Rico, Colorado* dated March 9.

II. Assessment of the Fluid Hazard

Fluid hazard is created by the water head and volume stored within the tunnel and associated workings. Both head and volume tend to increase both with increasing inflow to the mine workings and due to progressive clogging of the debris plugs over time. Tunnel fluid volume estimates are obtained from archival mine mapping that indicated the St. Louis Tunnel has a constant grade of 0.4 percent and 9-foot wide by 7-foot high minimum design dimensions. Actual mine dimensions based on floor / roof surveys indicate a nominal 8- to 9-foot as-built tunnel height. The Northwest and Southeast Crosscuts show a plan width of 7.6 feet and 10.3 feet, respectively,. No information is available on crosscut heights, but they are assumed to be 8.5 feet. Tunnel geometry information is depicted on **Figure II-1**. Conservatively assuming that nominal as-built widths are one (1) foot wider than design, the estimated tunnel volume by elevation is as shown on **Figure II-2**. Tunnel volume increases more significantly with increasing head once the in-by Northwest and Southeast Crosscuts at the back of the main tunnel are reached. However, uncertainties in the reaches relevant to this project as to actual crosscut geometry and possible additional mining after the dates of the available archival information may result in the volumes shown on **Figure II-2** being somewhat under or over estimated.

Periodic measurements of tunnel flow were conducted via various methods and various consultants since the 1970s. Water flow has been measured by a Parshall flume downstream of the tunnel (station DR-3) periodically since 2001 during discrete sampling events until 2011. In 2011, the flume was instrumented and continuous data has been collected since then. Modeling historic tunnel outflows indicates that they are influenced by seasonal precipitation / snowmelt infiltration and hydrogeologic storage in faults, fractures and overburden (Amec-FW, 2015[3]). The model was used to simulate a 60-year continuous tunnel flow output calibrated to all data, then analyzed for flow recurrence. The estimated recurrence interval tunnel discharges are estimated as follows:

Return Period (years)	Discharge (cfs)	Discharge (gpm)
5	2.23	1003
10	2.46	1103
25	2.75	1236
50	2.98	1337
100	3.20	1438

Tunnel water level is measured via the AT-2 and BAH-01 monitoring wells. AT-2 was instrumented in 2011 and continuous measurements have been collected since then. BAH-01 was hand measured periodically since 2011 and was instrumented for continuous measurement in September, 2015. Data is best illustrated by plotting tunnel head at both well locations (AT-2 and BAH-01) against flow at DR-3 as shown on **Figure II-2**.

As flows increase, head in the tunnel generally increases proportional to flow because the debris plugs are believed to be controlled by flow through porous media relationships (i.e., a linear Darcian regime) as illustrated by the sloping linear segments on **Figure II-3**. Head drops indicate that debris plugs exist between first water surface emergence below AT-2 and AT-2, and also further in-by between AT-2 and BAH-01. It is assumed that BAH-01 is representative of head in the rest (in-by portion) of the tunnel except for minimal conveyance loss head drop. More steeply sloped segments indicate lower

[3] Amec Foster Wheeler (Amec-FW). 2015. *Technical Memorandum: Development of the Rico Argentine Mine DR-3 Hydrologic Model*, submitted to Anthony Brown, BP. April 22.

permeability (i.e., more head required to drive the same flow). Higher projected y-axis intercepts (at DR-3 flow = 0) indicate higher "sills" resistant to flow (i.e., more area in the lower portions of the debris plugs with lower permeability, assumed due to increasing cumulative clogging). Comparison of linear flow versus head segments with time generally indicates a periodic stepwise increase in sill elevation and / or decrease in permeability.

The key conclusion from evaluation of the available flow and head data is that heads measured at AT-2 and BAH-01 are generally increasing over time for the same flow rate, indicating that the debris plugs are experiencing progressive clogging or collapse. As head in the tunnel increases, stored tunnel volume also increases as shown on **Figure II-2**. Although conditions are dynamic, a 25-year design flow of 1250 gpm (rounded up from 1236 gpm) is currently projected to result in a tunnel head of 8876 feet[4] based on extrapolation of the current tunnel flow / head relationship.

III. Failure Modes and Effects Analysis

Three (3) potential failure modes (PFMs) for the debris plug(s) and overlying colluvium at the St. Louis Tunnel were identified as documented in Preliminary Design Report, St. Louis Tunnel Hydraulic Control Measures (AECOM, 2013[5]) as follows: 1) excessive uplift (heave); 2) excessive exit gradient (blowout); and 3) slope instability. Geotechnical analyses indicated that an acceptable Factor of Safety (FS) was present for each of the PFMs when the water head in the tunnel (as measured at AT-2) was less than or equal to approximately elevation 8870 feet. As the head in the tunnel rises higher the FS for each of the PFMs decreases, reaching FS = 1 for slope stability at a head of 8881 feet at AT-2.

As discussed in Section II, hydraulic analyses indicate that the head in the tunnel would rise to approximately elevation 8876 feet during an estimated 25-year recurrence tunnel inflow event with an estimated peak flow of about 1250 gpm, assuming that the hydraulic conductivity of the debris plugs does not change from the Spring 2015 condition. Further hydraulic analyses were performed in order to assess the potential effects of an intentionally conservative, hypothetical breach of the debris plugs during a 25-year inflow event. These analyses indicated that without any interim risk reduction measures the breach flow from the tunnel would overtop the Flood Control Dike in several reaches resulting in direct discharge to the Dolores River, with the remainder of the flow inundating the Enhanced Wetlands Demonstration (EWD) facilities and the downgradient ponds to Pond 9 as shown on **Figure III-1**.

Given the results of the geotechnical and hydraulic analyses, it was determined that interim control measures should be developed and implemented to reduce the risk of debris plug breach and the resulting downstream effects to an acceptable level while a long-term hydraulic control alternative is selected, designed and constructed. The key design and operational criteria selected for the interim risk reduction measures are as follows:

1) Maximum design tunnel inflow of 1250 gpm (estimated peak of a 25-year recurrence inflow)
2) Design life of interim measures of five (5) years
3) Maximum head in tunnel at BAH-01 controlled to no higher than 8869 feet

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[4] All elevations are reported as above mean sea level (amsl).

[5] AECOM. 2013. *Preliminary Design Report, St. Louis Tunnel Hydraulic Control Measures, Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01, Rico, Colorado*; submitted to US EPA Region 8, Denver, CO. October 30.

4) Detention of all stored tunnel water in the event of debris plug breach (with controlled discharge downgradient)

As described in more detail in Section IV, these criteria will be met by installing a relief well system to control head within the tunnel and constructing a flow control structure (FCS) downgradient of the debris plugs to detain tunnel water released in the event of debris plug breach. These two measures together provide very substantial protection against debris plug breach and the resulting downstream effects up to at least the 25-year inflow event. The interim measures are being designed so that the relief well system can intercept and route the entire 1250 gpm peak design flow safely around the debris plugs to discharge into the spillway stilling basin that will be constructed at the downstream toe of the FCS, and then routed downgradient in a controlled manner. The robustness of these measures is illustrated by the following factors:

1) The relief well pumping system accommodates the unlikely event of sudden or short-term total plugging by collapse or blinding of the debris plugs (i.e., no flow passing through the debris plug).
2) The pumping system will include two wells manifolded at the surface and two pumps to provide location and mechanical redundancy; either pump alone will have the capacity to reliably meet the 1250 gpm maximum design discharge.
3) The selected pumps are being sized with approximately 20 percent reserve capacity to pump up to approximately 1500 gpm in the event of an inflow event exceeding the design inflow; 1500 gpm (rounded up from 1438 gpm) is the estimated peak flow for a 100-year inflow event.
4) The FCS is sized to detain sudden release of the total stored water in the tunnel at the maximum design head of 8869 feet and release the water downgradient in a controlled manner that can be accommodated on site without uncontrolled release to the Dolores River.

Final design of the pumping system and FCS are currently in progress. The FCS is being designed to fully contain the tunnel water during a breach event and release the detained water at a controlled rate to further minimize downgradient on-site effects. If possible, the maximum rate of discharge from the FCS will be designed to not exceed the capacity of the existing 25-year, 24-hour storm drainage system on site. Further modeling will be performed to document the effectiveness of the final FCS design.

IV. Description of the Work to be Performed

A. Key Expertise

The work planned for the 2016 Rico work season will involve a group of qualified professionals completing the design, field oversight, safety and construction. The team is well experienced with the specific conditions, requirements and difficulties associated with the Rico site.

The design team is comprised of civil engineers, geotechnical engineers, geologists, hydrologists, geochemists and safety professionals. The onsite field oversight team is staffed with civil engineers, a geotechnical engineer, a geologist and a safety professional. This team will be onsite during all work implementation, which includes relief well drilling, pumping system installation, flow control structure (FCS) construction, and supporting earthwork. As multiple tasks are being performed simultaneously, Atlantic Richfield will also be coordinating these activities. The field oversight team has been actively involved and has contributed to the design process, with particular focus on critical steps involved with the implementation of these interim risk reduction measures.

The contractors performing the actual construction and drilling work will be pre-qualified, employing a rigorous vetting procedure. The current environmental and earthwork contractor has been onsite for the past 2 years and will continue to complete earthwork activities. The drilling contractors are currently providing proposals for the relief well installation. Pumping system contractors are currently being identified and vetted. The FCS contractor is yet to be determined. These bidders will be qualified employing the project vetting process.

The Rico project teams are outlined below:

<u>Design:</u>

- Terry Moore, PhD (BP) – Integrity management and technical coordination
- Chuck Blanchard, PE (BP) – Technical review and support
- Sandy Riese PhD, CHG, LP, PG (En-Sci) – Technical coordination, geochemistry and technical support
- Doug Yadon, PE, GE, PG, CEG – Overall technical lead and coordination, lead relief well design
- Scott Cole, PE (AECOM) – Lead pumping system design, design support during construction
- Mike Clark, PE (AECOM) – Lead electrical, instrumentation and controls design, design support during construction
- Rich Keeland, PE and Alan Jewell, PE (Pioneer) - Lead FCS design and geotechnical engineering
- Christopher Sanchez, CSP and Mark DeFriez, PE (Anderson Engineering) - Relief well pipeline design, drill pad design and technical support for relief well drilling
- Corey Hixenbaugh (AEEC) - Telemetry monitoring and technical support

<u>Field Oversight:</u>

- Alan Jewell, PE (Pioneer) - Site wide geotechnical assurance, FCS construction oversight
- Kevin Cosper, PE (Anderson Engineering)- Relief well drilling oversight
- Christopher Sanchez, CSP (Anderson Engineering) Field SLT coordination, site safety, relief well procurement and drilling oversight
- Benjamin Loomis, EIT (Anderson Engineering) Field coordination, safety, water management and SIMOPS (Simultaneous Operations)
- Brad Florentine, PE (AMEC-FW) - pumping system procurement and FCS construction oversight

<u>Implementation Contractors:</u>

- Anderson Engineering (Subcontractor: TBD) - Drilling
- USA Environment – General Earthwork
- AMEC-FW (Subcontractor: TBD) - Pumping System
- Flood Control Structure – TBD

B. Steps to Minimize Uncontrolled Release of Fluids

Drilling of Relief Wells (see **Figures IV-1** and **IV-2**):

- Install two new nominal 10-inch angled wells (with 8-inch casing) penetrating the SLT approximately 25 feet apart upgradient of the reportedly lagged portion of the tunnel in a reach characterized as competent sandstone of the Hermosa Formation.
- Locate the wells on the existing bench at the east side of the Soil Lead Repository.
- Space the well collars approximately 50 feet apart at the surface to minimize the potential for interference between the two holes during drilling.
- Complete both wells with 8-inch nominal diameter steel casing to serve as suction pipes for the pumping system described below.

Pumping System (see **Figures IV-3** through **IV-7**):

- Manifold the suction pipes in the pump station, but maintain flexibility using isolation valves to operate either pump with either casing suction pipe.
- Install a pump building comprised of a pre-engineered metal building (PEMB) on a concrete pad with footings to provide protection from frost heave. Design the foundation to accommodate a CMU masonry block building if desired instead of the PEMB
- Install two centrifugal pumps each with a variable frequency drive (VFD) and a vacuum-assisted self-priming system in the new pump building. If necessary to expedite pumping during the 2016 spring freshet, consideration will be given to use of a temporary diesel-driven pump until the centrifugal pumps are installed.
- Provide piping and valving to operate the centrifugal pumps in a lead – lag mode, such that both pumps are utilized sequentially and thereby maintained in good working order; either pump operating will draw from both relief wells via the manifold piping, or the flexibility described above in the second bullet.
- Provide water level (head) monitoring with pressure transducers installed in each relief well.
- Provide for metering pump discharge flow inside the pump building.
- Install a manhole outside the pump building to provide a pressure break for the pump discharge for a gravity discharge conveyance system.
- Route pump discharge in a buried pipeline from the manhole to a location at the stilling basin for the Flow Control Structure as noted below.
- Eliminate the existing 120/220 volt overhead feed to the Lime Plant Building. Provide new electrical service from the existing San Miguel Power transmission line on site via buried conduit to the Lime Plant Building and continuing to the pump building. Install a suitable transformer to step down the power at the Lime Plant Building to replace the existing electrical service. The new 480v, 3-phase service will continue underground to the new pump station to service the pumps and VFDs.
- Install electrical components, controls and instrumentation in the pump building to operate and monitor the pumping system.
- Pumps will be automatically level controlled by one of the pressure transducers in the relief wells; manual operator override of the automated system will be provided.
- Provide cabling and / or radio signals from the pump building to the Lime Plant Building to integrate pumping system monitoring and controls with the existing site SCADA system.

- Provide an on-site emergency diesel generator, heated fuel storage, and auto transfer switch gear to back-up commercial power. Size to serve the pumping system, new aeration blowers, and other on-site electrical demands.

Flow Control Structure (see **Figures IV-8** and **IV-9**):

- Construct a gabion flow control structure (FCS) below the lower debris plug and above the existing static mixer between the slope above the collapsed, open channel portion of the SLT and the Soil Lead Repository.

- Provide a spillway section in the crest of the FCS to safely pass flood flows from a hypothetical breach of the debris plugs in the very unlikely event of clogging of the FCS discharge culvert or debris plug breach flow and volume from an event greater than the design inflow.

- Include a gabion mattress stilling basin at the downstream toe of the FCS to receive discharges from the relief well pumping system and spillway discharges in the event of either of the scenarios described in the previous bullet.

- Install an HDPE culvert beneath the FCS in the collapsed tunnel channel to pass normal discharges from the tunnel and to rapidly, but in a controlled manner, empty tunnel water detained by the FCS in the event of debris plug breach.

- Provide for routing pumping system discharges from the FCS stilling basin via the current conveyance system to treatment at the EWD or bypass to Pond 15.

Operation:

- Automated pumping of the relief well system to maintain head within the SLT at BAH-01 to no greater than elevation 8869 feet for inflows up to the estimated 25-year recurrence event of approximately 1250 gpm. The pumping system controls will permit the operator to adjust the 8869 feet pumping level if / as needed.

- Monitoring of pump discharges using a magnetic flow meter installed in the pump station building.

- Monitoring of SLT flows passing through the debris plugs and flows from the pumped relief well system at the existing DR-3 station.

- Monitoring of water elevations within the SLT at AT-2, BAH-01 and both new relief wells. Data from only one pressure transducer will control the pumps.

- Review of data from the above monitoring on no less than a weekly basis for any indications of additional changes in debris plug hydraulic conductivity and thereby discharge capacity.

- Periodic maintenance of pumping system components and instrumentation.

- Frequent observations of system components on at least a weekly basis during non-winter months.

- Implementation of additional measures, if needed.

- Recordkeeping.

C. Major Uncertainties and Risks

Implementation of the interim risk reduction measures described above in Section IV B involve certain uncertainties and risks. Uncertainties and risks identified to date are presented below together with currently envisioned mitigation measures. We will continue to evaluate risk and potential mitigation throughout the remainder of design and during implementation.

1) Tunnel heads higher than anticipated during drilling of relief wells
    - Continuously monitor heads in tunnel at AT-2 and BAH-01
    - Provide T-fitting on drill collars and temporary diversion piping to safely route gravity flow in relief well casing during drilling to existing tunnel discharge conveyance channel downstream of debris plug
    - Utilize AT-2 as gravity or siphon relief well if / as needed
    - Discontinue drilling if excessive tunnel heads occur

2) Drilling method causes excessive vibrations
    - Real-time vibration monitoring in terrain trap
    - Continuous monitoring of head in AT-2 and BAH-01
    - Stop drilling if excessive vibration or unexplained changes in tunnel head
    - Implement alternative drilling method

3) Drilling resulting in high conductivity annular conduit around casing allowing tunnel water seepage into colluvium and ultimately to debris plugs resulting in changes in gradient and geotechnical instability
    - Grout the annulus in the rock portion of the drill holes
    - Continuous monitoring of head in AT-2 and BAH-01
    - Visual monitoring for seepage discharge from colluvium in north wall of terrain trap

4) Damage to the 8-inch casing during installation makes the casing unusable as a direct suction pipe as needed for the pumping system
    - Install a slip-lined carrier pipe in the casing pipe, with decreased flow rate due to reduction in internal pipe diameter
    - Make repairs utilizing remotely operated tools if feasible to maintain suction pipe design diameter
    - Drill replacement relief well and install new casing

5) Destabilizing wall and/or roof (crown) of tunnel upon drill hole penetration
    - Target area of most competent appearing rock per archival tunnel mapping
    - Reduce drilling rate and down pressure as target is approached
    - Terminate drilling if drill action or cuttings return indicate encountering wood supports
    - Perform downhole camera inspection to assess conditions if wood supports are encountered

  - Utilize appropriate drilling bit to penetrate wood support (posts or lagging) if present
  - Perform downhole camera inspection immediately upon penetration into tunnel to verify stability or assess conditions if instability is encountered

6) Equipment ground disturbance, vibration and loading during FCS construction

  - Keep FCS well downstream of debris plug
  - Do not allow heavy equipment into terrain trap
  - Continuously monitor AT-2 for unanticipated changes in head
  - Real-time vibration monitoring in terrain trap
  - Minimize foundation excavation depth to avoid potential increase in groundwater gradient through debris plugs

7) Rapid changes in gradient through debris plugs during relief well pumping system start-up and testing

  - Control pumping rate with VFD controllers to avoid rapid head changes in the tunnel and thereby in the debris plugs
  - Control self-priming, and if required manual priming, to avoid rapid head changes in the tunnel and thereby in the debris plugs
  - Continuous monitoring of head in AT-2 and BAH-01
  - Terminate testing if any unanticipated changes occur in tunnel head at AT-2 or BAH-01

D. Schedule

The construction work season in Rico is typically from May to November. During this time minimal snow is present at the site and temperatures range from sub-freezing to the mid to high 80 degrees F. These conditions are generally conducive to substantial construction. Heavy rains occur generally from early July through September and can cause construction delays during this period. Temperatures from December through April in Rico are cold. Late fall and winter snowfall can be significant. The cold temperatures and snow accumulation can significantly hamper and make unsafe work activities.

The work activities planned for the Rico 2016 construction season are scheduled to start in late April and continue through a portion of September. The tentative schedule for the major tasks is provided below:

- Site Access and Initiate Mobilization: April 25, 2016
- Relief Well Drilling: May 2016 – July 2016
- Pump System: May 2016 – August 2016
- Flow Control Structure: June 2016 – September 2016
- Demobilization: September 2016

Given the objective of the interim risk reduction measures described herein to protect against potential debris plug breach, the stretch goal is to have at least one relief well and one pump operating by mid June when seasonal peak discharge from the St. Louis Tunnel is anticipated. However, this goal will not be allowed to introduce any unsafe practices or conditions during any portion of the implementation work. Work will be completed at the earliest practical dates consistent with site safety.

Figures

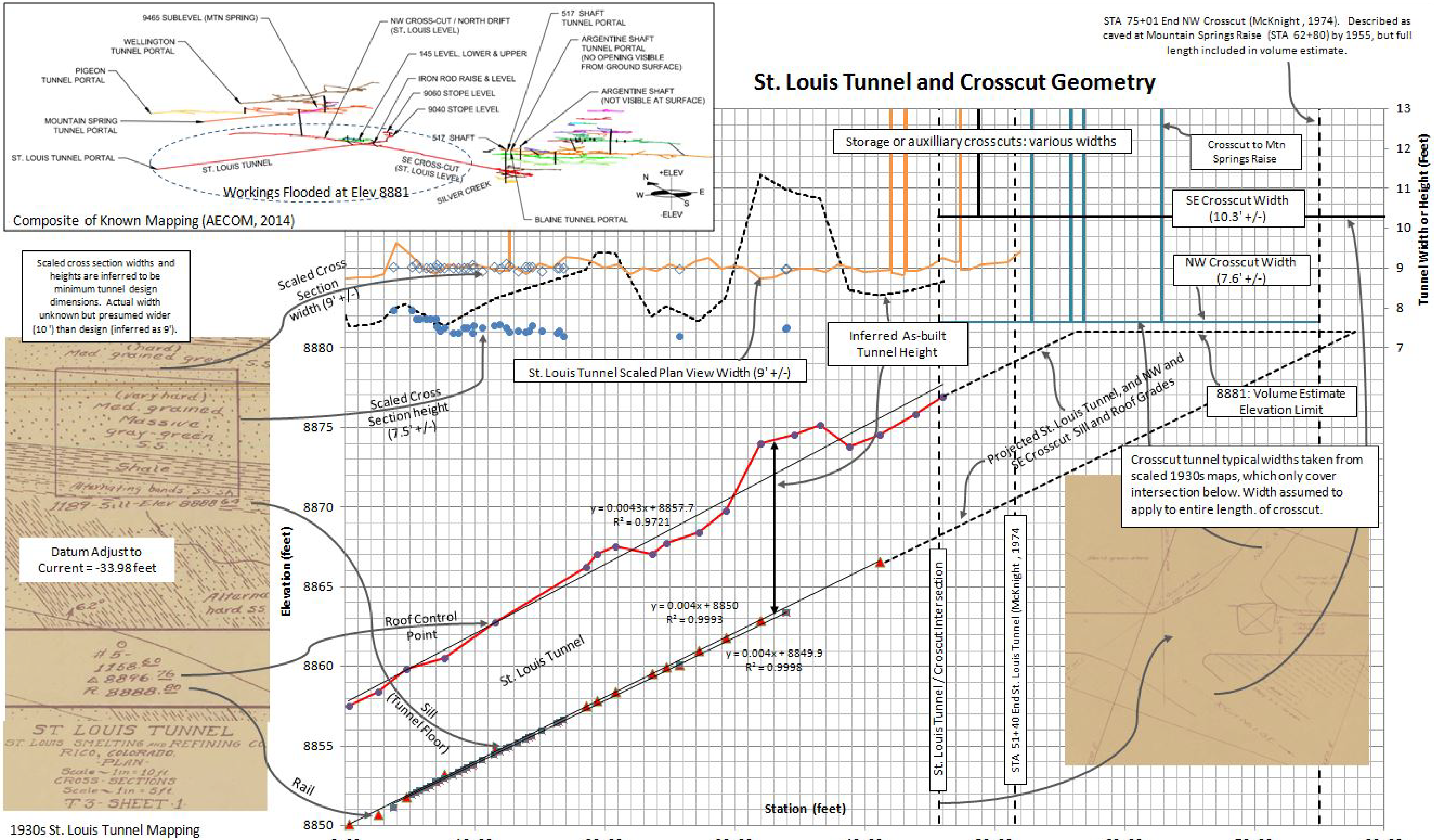


Figure II-1 – St. Louis Tunnel and Crosscut Geometry

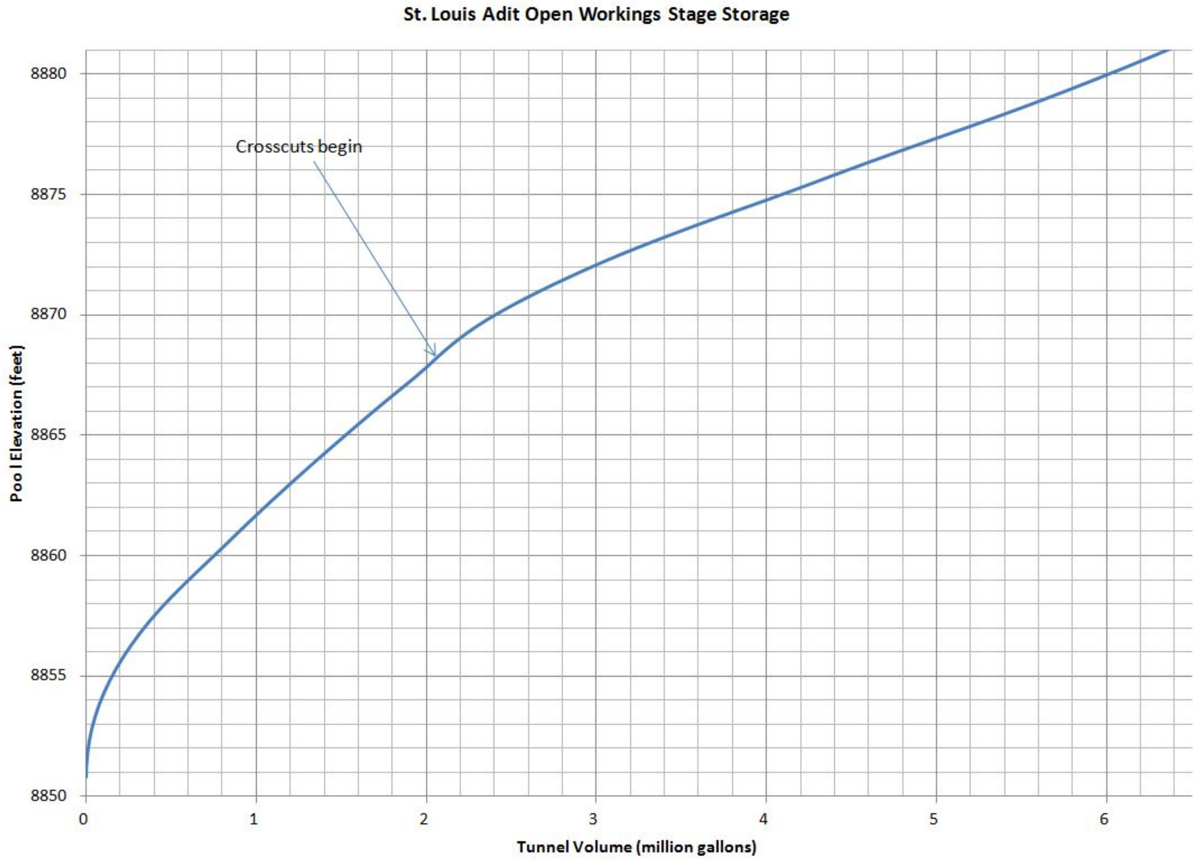


Figure II-2 – St. Louis Tunnel Open Workings Stage Storage Curve

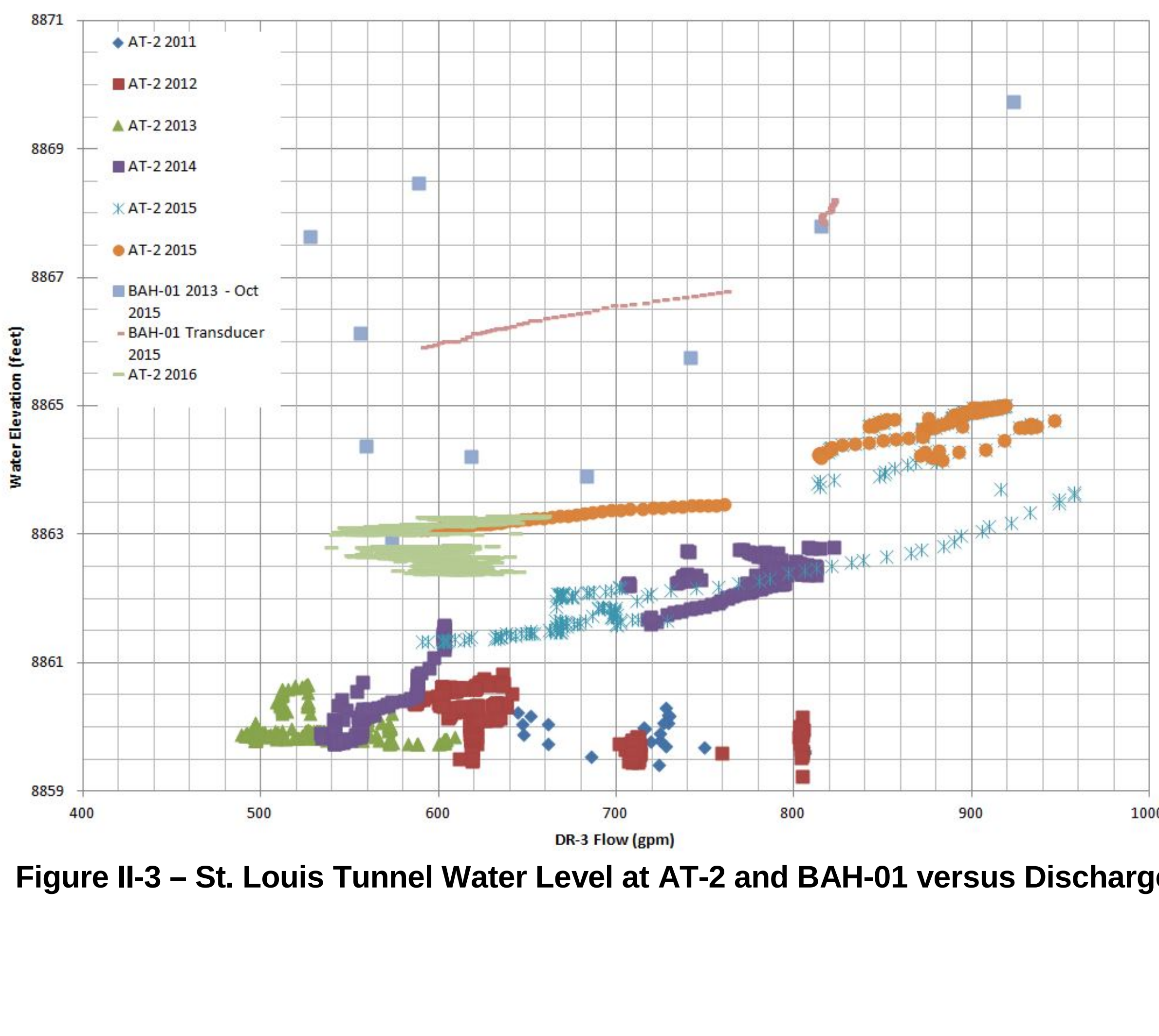


Figure II-3 – St. Louis Tunnel Water Level at AT-2 and BAH-01 versus Discharge

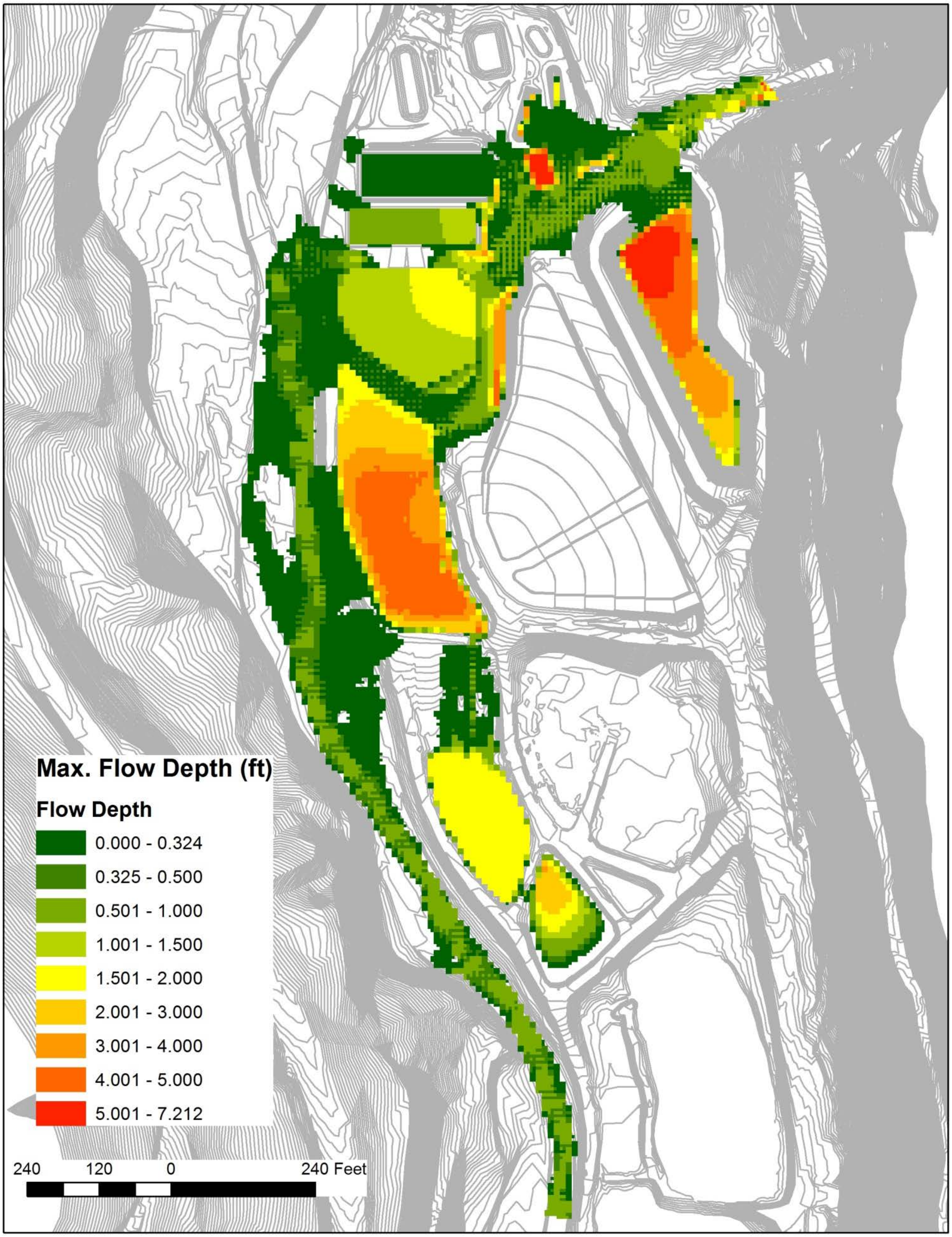
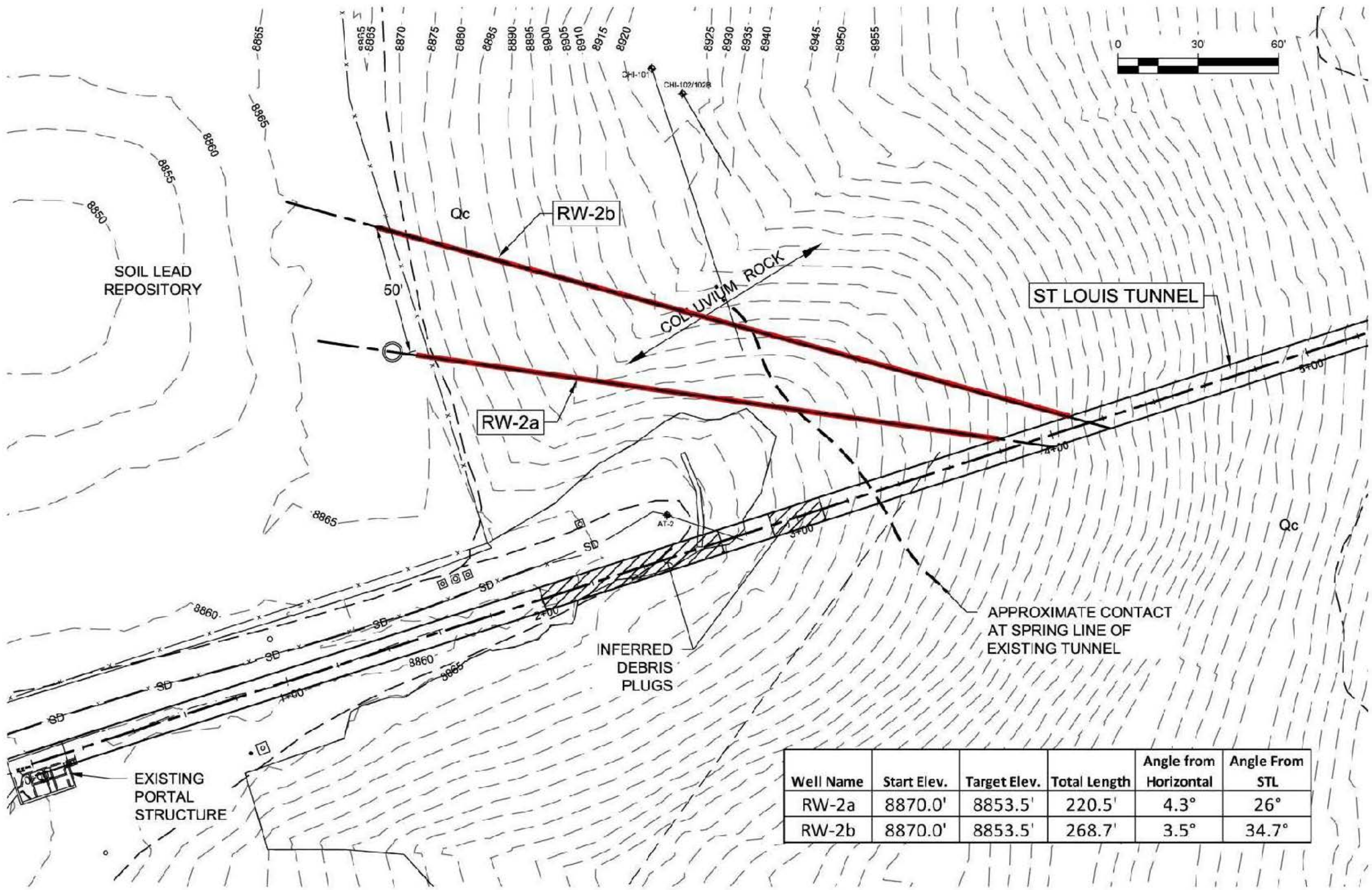


Figure III-1 – Hypothetical Flood Inundation Due to Breach of Debris Plugs With No Interim Risk Reduction Measures

Figure IV-1 – Relief Wells Plan



Well Name	Start Elev.	Target Elev.	Total Length	Angle from Horizontal	Angle From STL
RW-2a	8870.0'	8853.5'	220.5'	4.3°	26°
RW-2b	8870.0'	8853.5'	268.7'	3.5°	34.7°

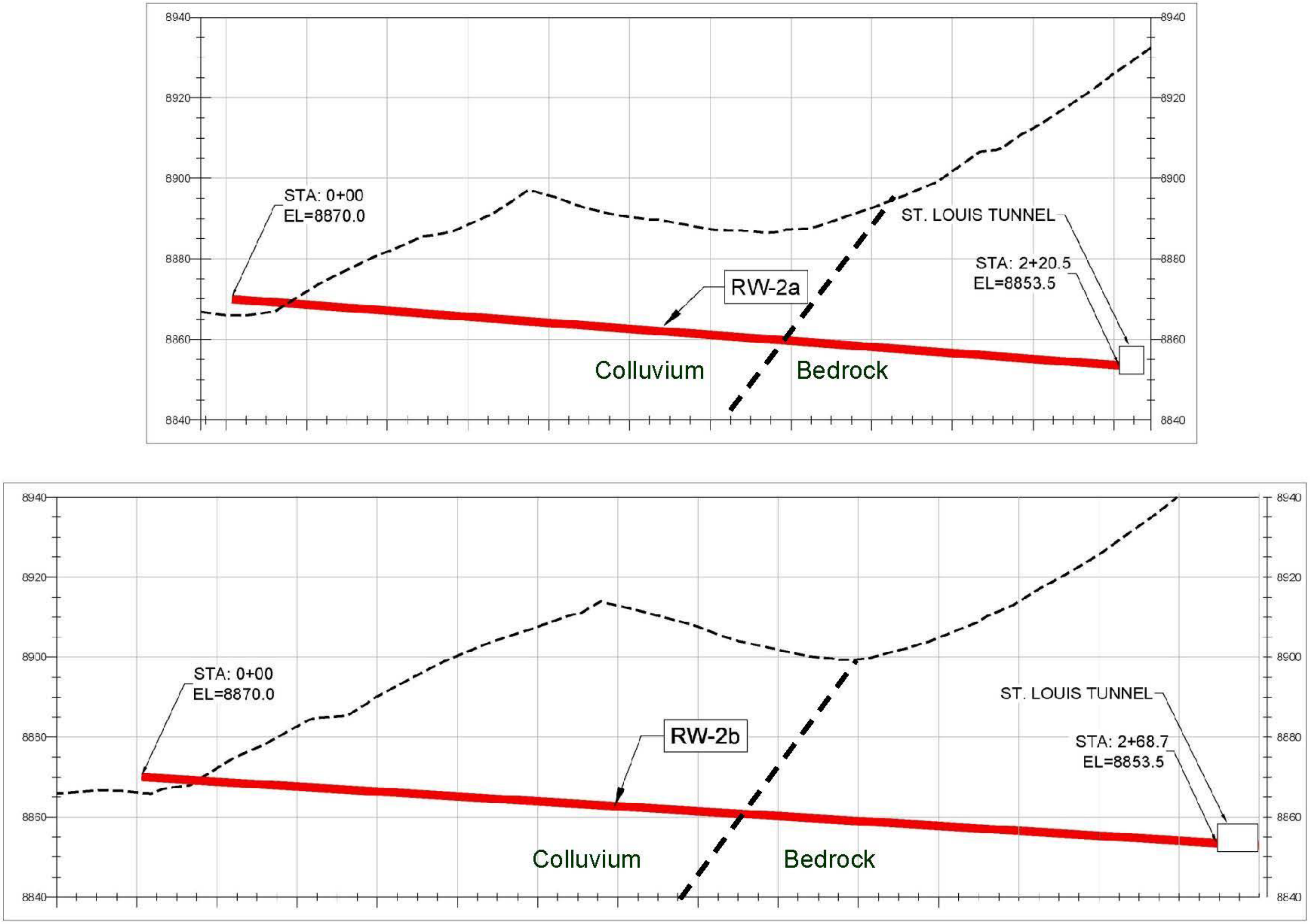


Figure IV-2 – Relief Well Profiles

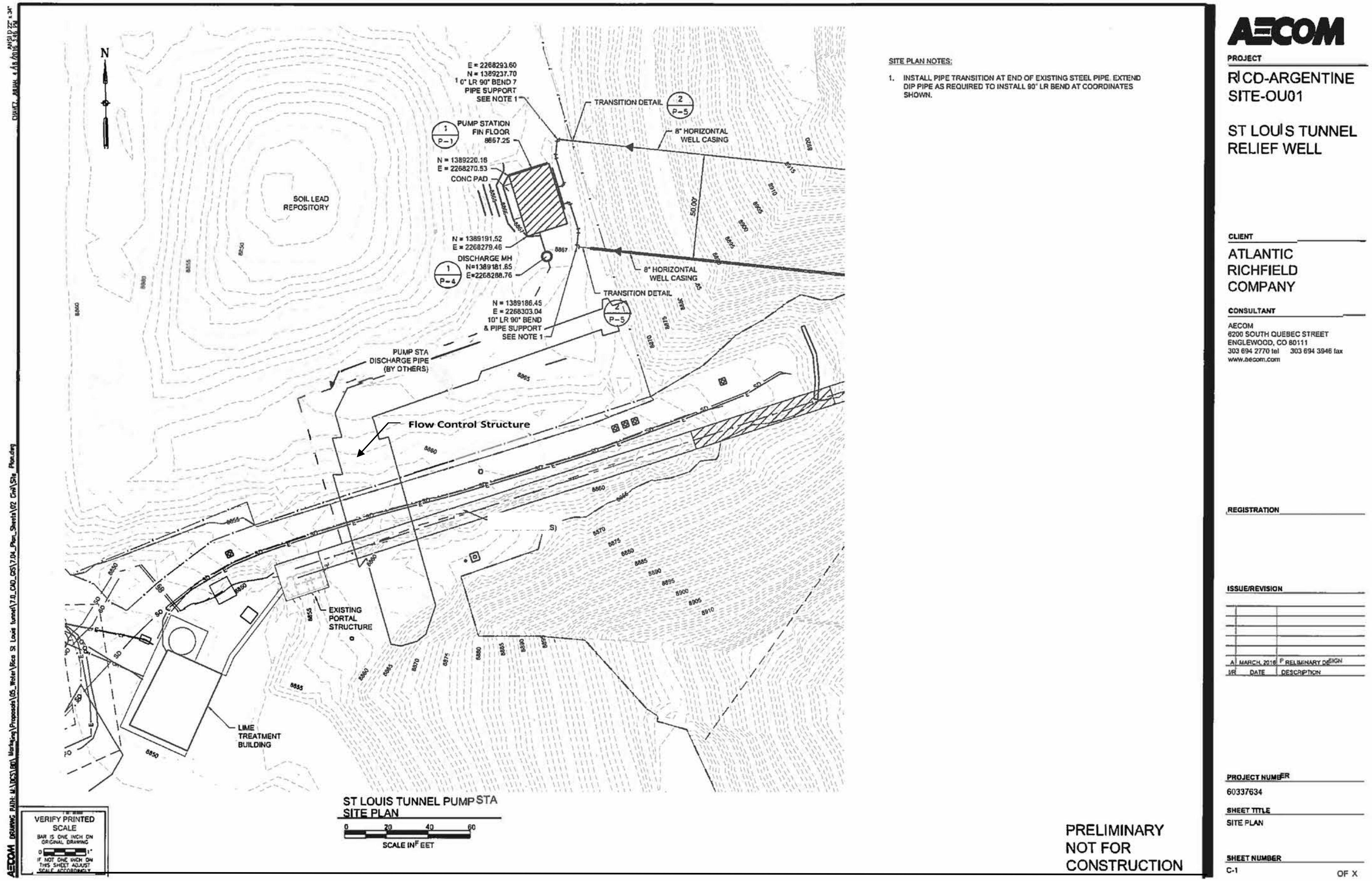


Figure IV-3 – Pumping System Site Plan

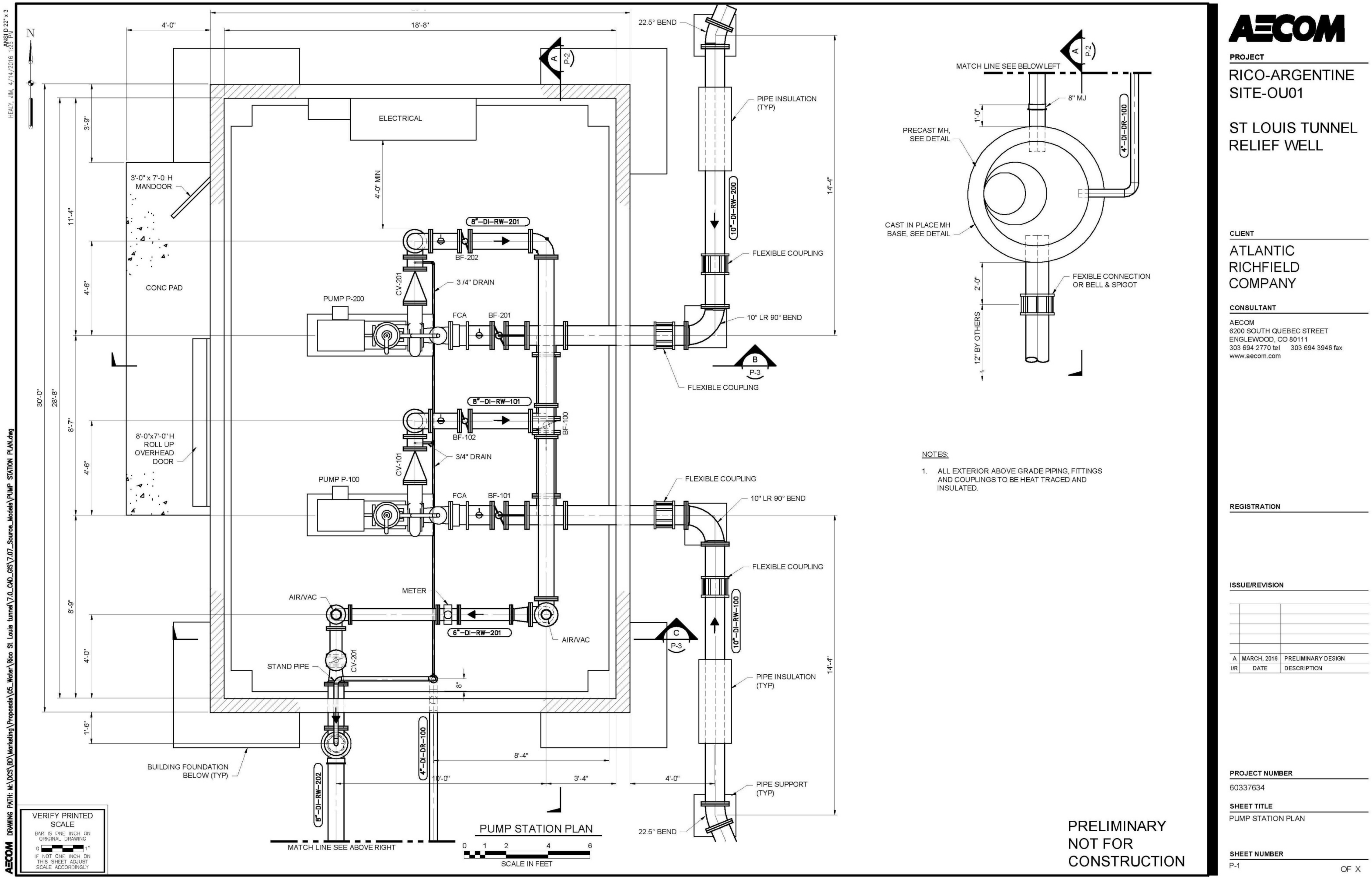


Figure IV-4 – Pump Station Plan

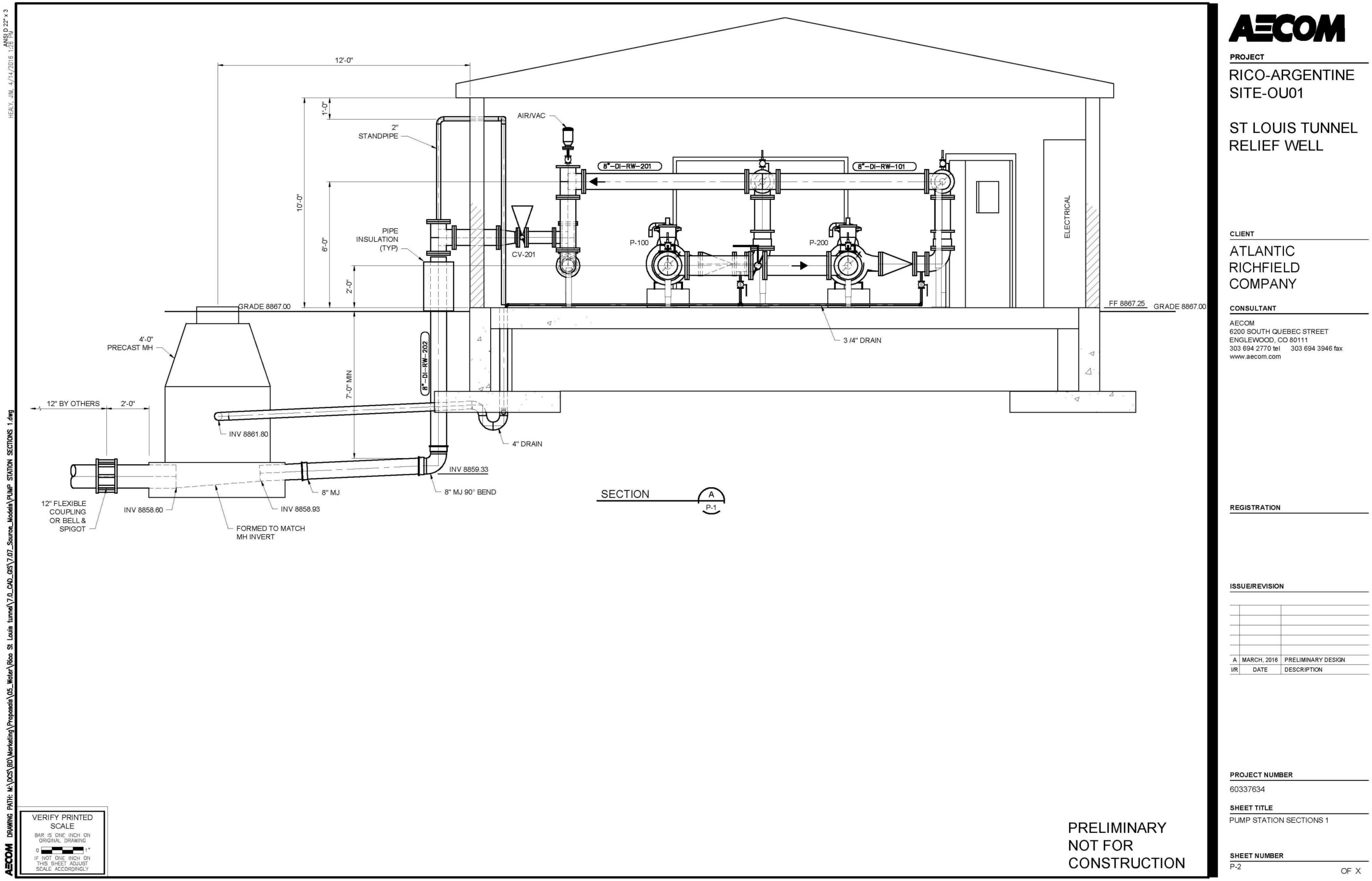


Figure IV-5 – Pump Station Section A

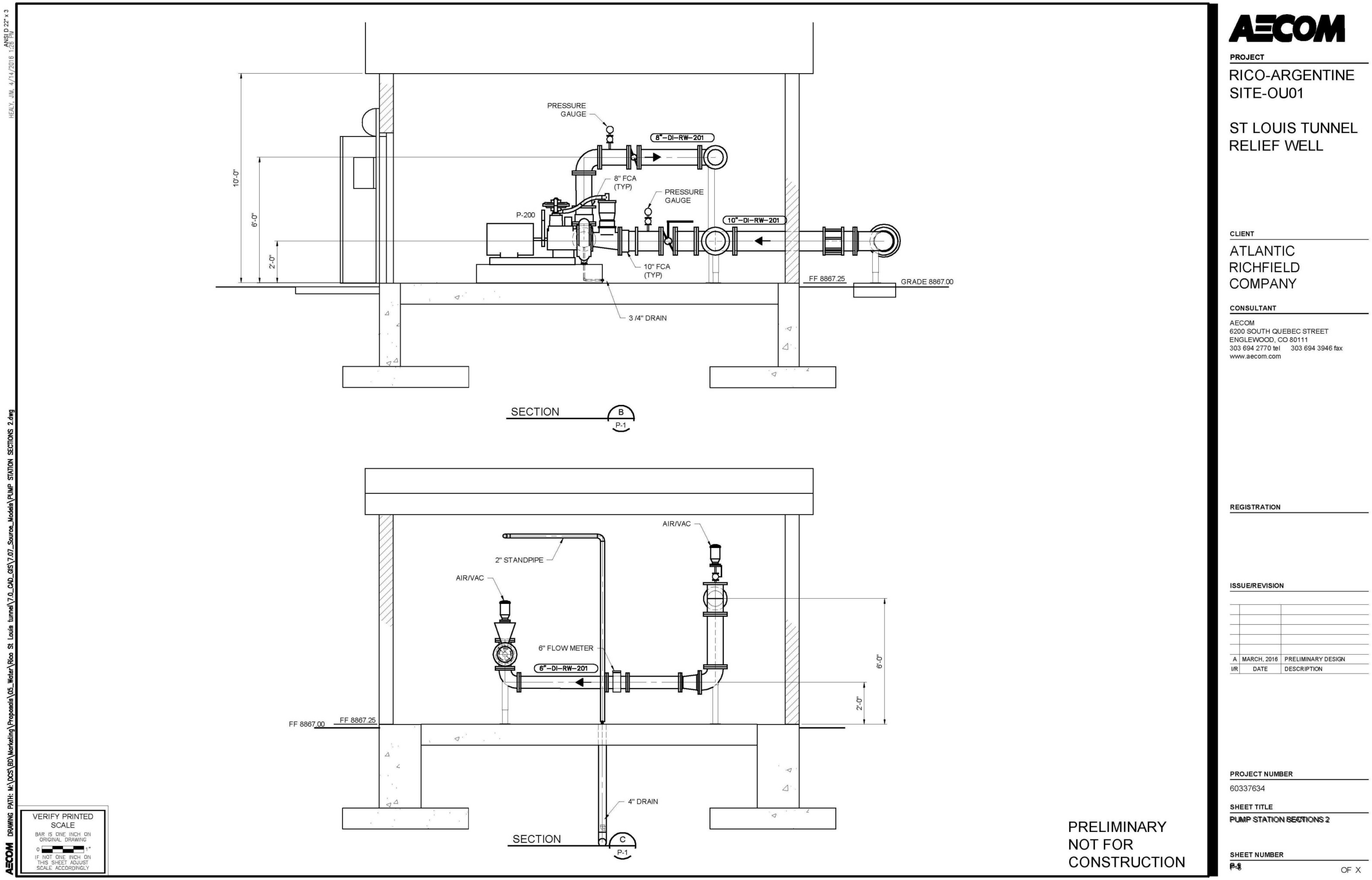


Figure IV-6 – Pump Station Sections B and C

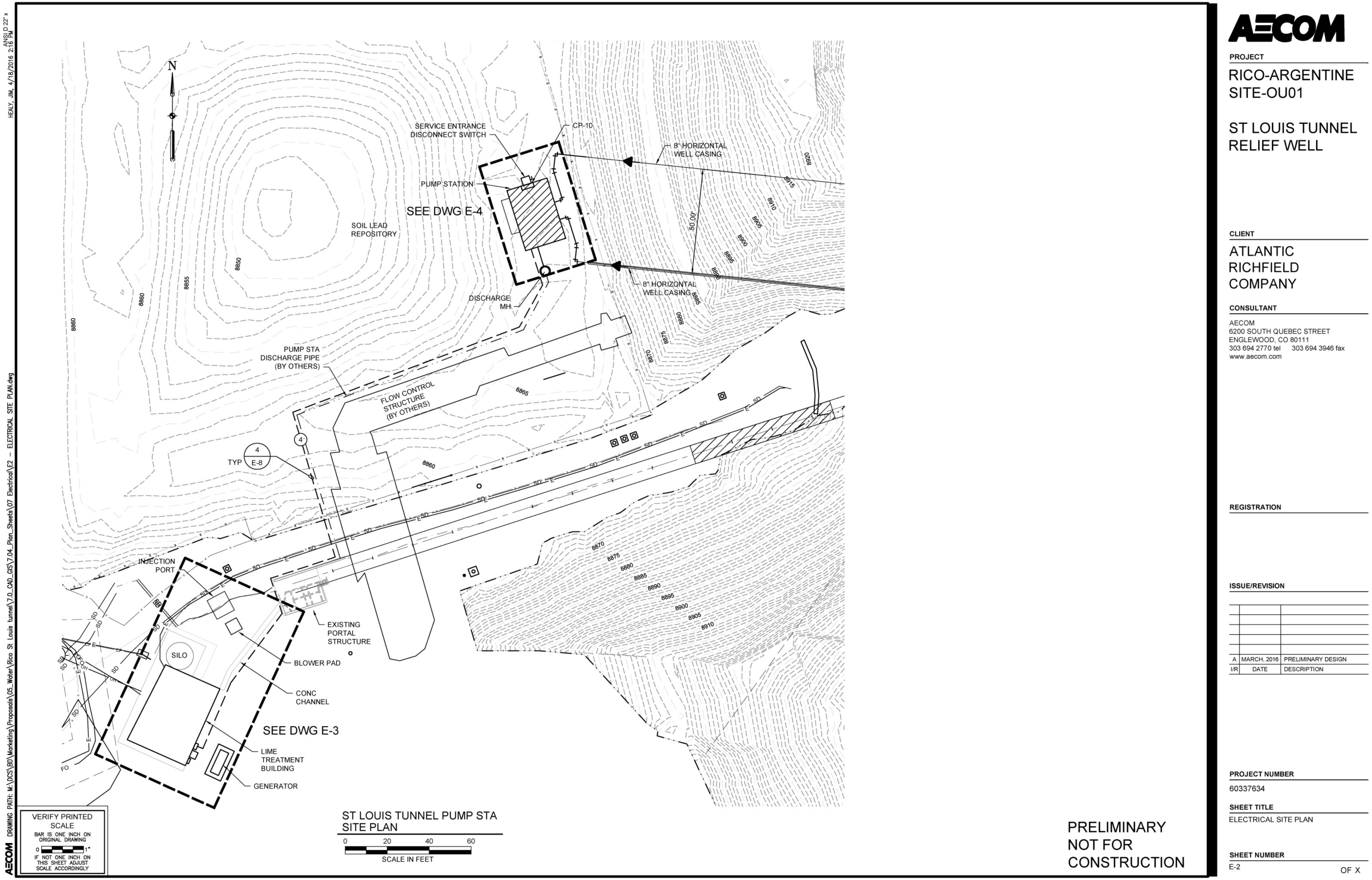


Figure IV-7 – Electrical Site Plan

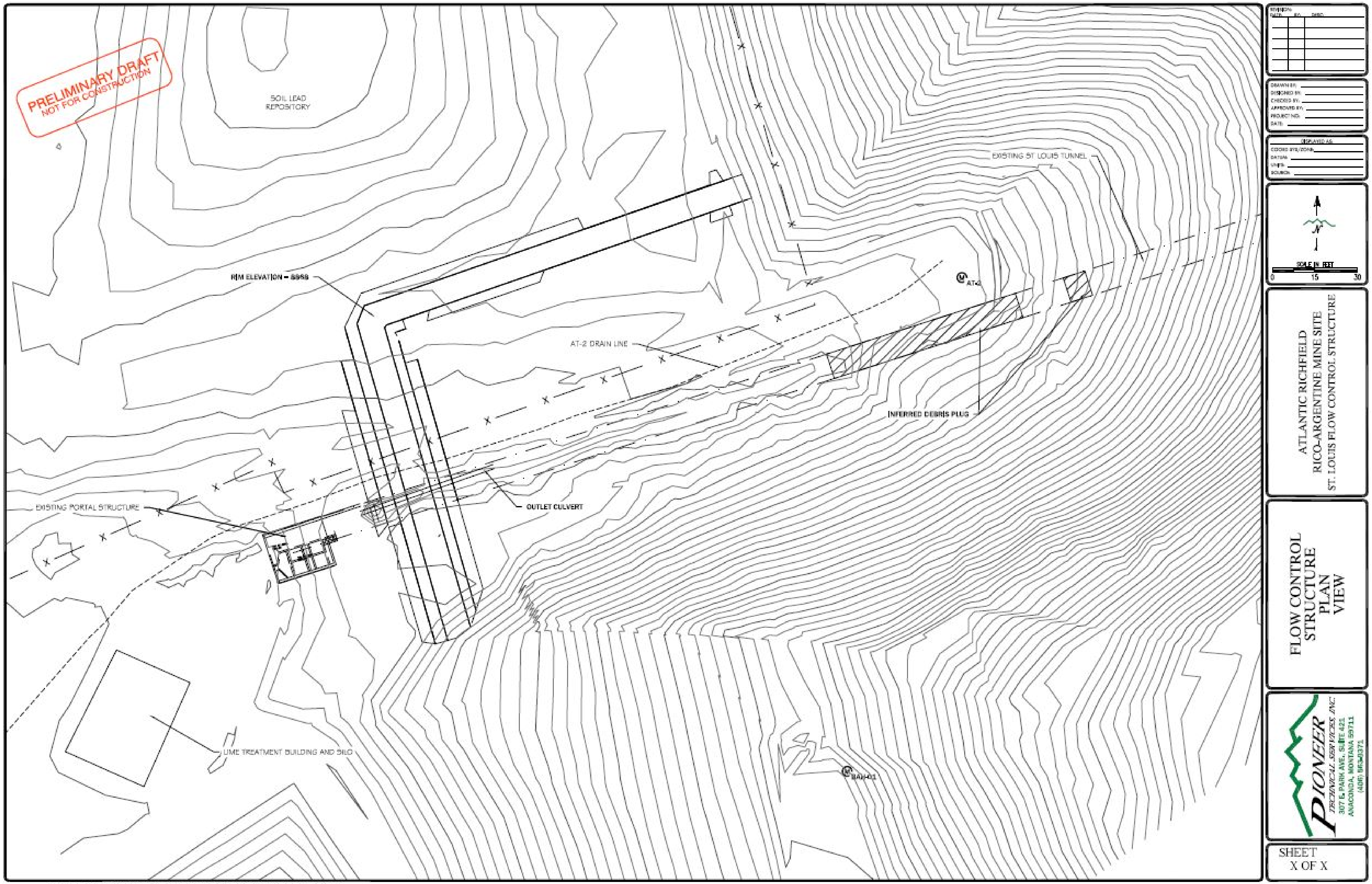


Figure IV-8 – Flow Control Structure Plan

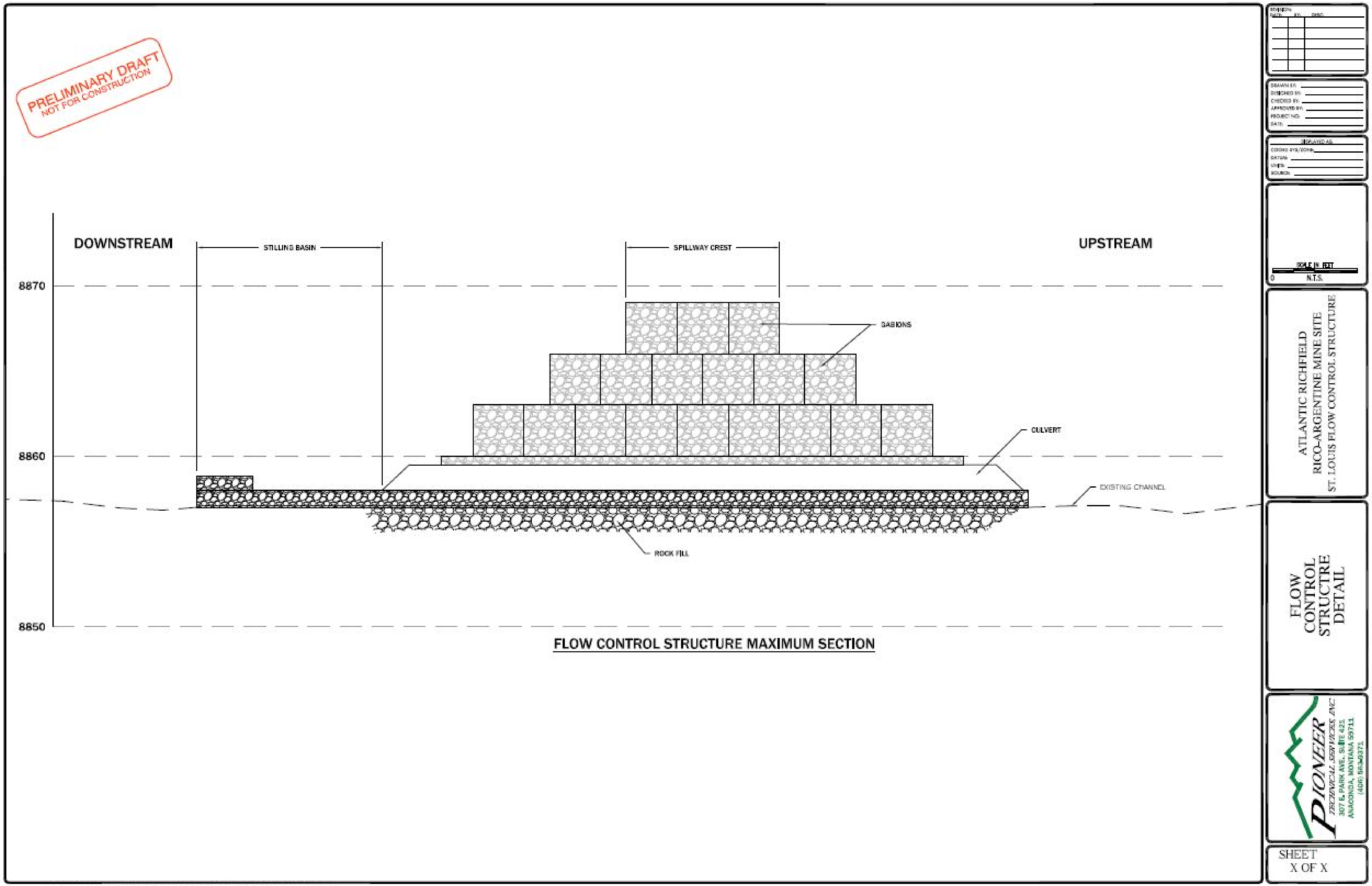


Figure IV-9 – Flow Control Structure Maximum Section